H04R1/10 (11) Publication number: **0 421 681 A2**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **90310624.3**

(22) Date of filing: **28.09.90**

(51) Int. Cl.5: **H04R 1/10**, H04R 5/033, H04R 1/28

(30) Priority: **30.09.89 JP 255797/89**

(43) Date of publication of application: **10.04.91 Bulletin 91/15**

(84) Designated Contracting States: **DE FR GB NL**

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(54) **Electro-acoustic transducer and sound reproducing system.**

(57) An electro-acoustic transducer comprising
an electro-acoustic transducer accommodated in a cabinet, and
a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said cabinet,
said sound guide tube being of a lesser diameter than the external acoustic miatus to allow at least the sound radiating end of the sound guide tube to be introduced into the external auditory miatus.

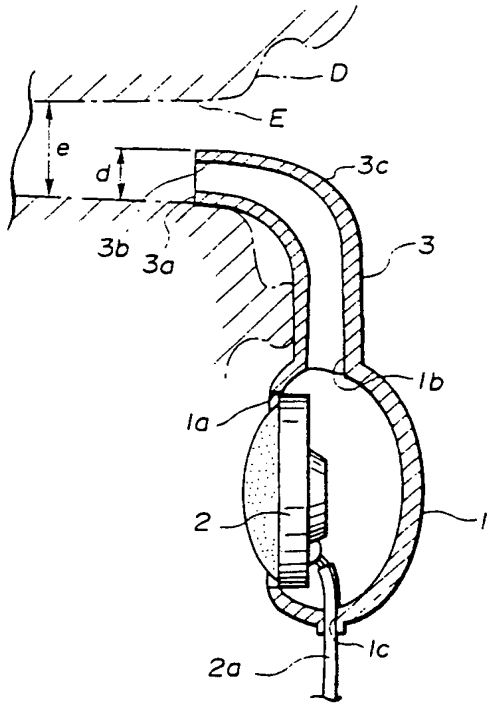

FIG.1

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ELECTRO-ACOUSTIC TRANSDUCER AND SOUND REPRODUCING SYSTEM

This invention relates to an electro-acoustic transducer for sound reproduction and a sound reproducing system using an electro-acoustic transducer or transformer.

Prior electro-acoustic transducers or sound reproducing systems include headphones and earphones.

The aforementioned electro-acoustic transducer comprises an electro-acoustic transducer unit for converting electrical signals representing the acoustic signals into sound. One well-know form of electro-acoustic transducer is the type of headphone device which is adapted for supporting a pair of electro-acoustic transducer units in opposition to both auricles of the user.

Other sound reproducing system also includes a pair of speaker units as the sound reproducing device arranged for converting electrical signals into sound. In one form, the speaker unit includes a speaker unit having a diaphragm and functioning as the sound reproducing unit and a speaker cabinet accommodating the speaker unit with the sound radiating side facing to the outside. With such a sound reproducing system, the speaker device is arranged in front of and for facing to the listener to effect sound reproduction via the speaker device.

Meanwhile, in the above described headphone device, the electro-acoustic transducer unit constituting the transducer is in close proximity and faces towards the listener's tympanic membrane, so that standing waves may be produced between the transducer unit and the tympanic membrane; in those circumstances the listener may feel an oppressed sensation due to the standing waves or feel as if the sound source were within his head.

With the above described electro-acoustic transducer, the electro-acoustic transducer unit is supported in a position where it substantially closes the listener's external auditory miatus so that the listener using the electro-acoustic transducer may feel unable to hear external sounds. Thus the use of the electro-acoustic transducer during walking on the road or driving a vehicle or car may endanger safe walking or driving since the user may be oblivious to the external situation.

With a cabinet loudspeaker system, the requirement of optimum sound reproduction over a wide frequency range including the lower frequency range tends to require an increase in the volume of the speaker cabinet constituting the speaker device and/or an increase in the area of the diaphragm of the speaker unit. If the cabinet volume or diaphragm area are increased, the size of the apparatus is increased.

On the other hand, with a sound reproducing system in which the size of the apparatus is increased to enable sound reproduction over a wide frequency range, it may be occasionally impossible to effect sound reproduction at a sufficiently high sound pressure without causing inconvenience or disturbance to the neighbours, for example, in congested housing circumstances.

In view of the foregoing, an object of one aspect of the present invention to provide an electro-acoustic transducer which, when arranged as a headphone device or an earphone device, does not give rise to oppressed feeling or a feeling as if the sound source were within the user's head.

It is an object of another aspect of the present invention to provide a sound reproducing system which is capable of satisfactorily reproducing sound over a wide frequency range including the low frequency range without unnecessarily increasing the size of the system or inconveniencing the neighbours.

According to the present invention, there is provided an electro-acoustic transducer comprising
an electro-acoustic transducer accommodated in a cabinet, and
a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said cabinet,
said sound guide tube being of a lesser diameter than the external acoustic miatus to allow at least the sound radiating end of the sound guide tube to be introduced into the external auditory miatus.

The invention also provides a sound reproducing system comprising
a sound reproducing apparatus for receiving electrical signals and transducing them into sound, and
an electro-acoustic transducer including an electro-acoustic transducer unit accommodated in a cabinet, and a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said cabinet,
said sound guide tube having at least the sound radiating end of a lesser diameter than the external auditory miatus to permit said sound radiating end to be introduced into the external auditory miatus,
said electro-acoustic transducer being adapted for reproducing at least the low-frequency component of the frequency range of the acoustic signal of the sound reproduced by said sound reproducing apparatus.

With the electro-acoustic transducer of the present invention, the sound guide tube adapted for conducting the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet towards the outside of the cabinet has at least its sound radiating end of a lesser diameter

than the external auditory miatus so that the sound radiating end may be inserted into the external auditory miatus. Thus the sound may be conducted into the inside of the external auditory miatus without stopping the external auditory miatus.

The sound reproducing system according to the present invention is so arranged and conducted that the sound may be reproduced by the sound reproducing apparatus adapted for being supplied with acoustic signals and for converting the acoustic signals into sound for reproduction thereof, and that the electro-acoustic transducer adapted for converting at least the low-frequency component of the acoustic signals supplied to said sound reproducing apparatus conducts the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet towards the outside of the unit, while radiating the sound into the external acoustic miatus by way of a sound guide tube having at least its sound radiating end of a lesser diameter than the external auditory miatus to permit the sound radiating end to be inserted into the external auditory miatus without stopping the external auditory miatus. In this manner, both the sound reproduced by the sound reproducing apparatus and the sound reproduced by the electro-acoustic transducer unit of the electro-acoustic transfer may be heard simultaneously.

The invention will be further described by way of non-limitative example with reference to the accompanying drawings, in which:-

Figure 1 is a diagrammatic cross-sectional view showing the construction of an embodiment of electro-acoustic transducer according to the present invention.

Figure 2 is an equivalent acoustic circuit diagram showing acoustic characteristics of the electro-acoustic transducer.

Figure 3 is a chart showing frequency characteristics of the reproduced sound of the electro-acoustic transducer.

Figure 4 is a circuit diagram showing the construction of a correction circuit for correcting the frequency characteristics of the electro-acoustic transducer.

Figure 5A is a side view showing the state in which the electro-acoustic transducer arranged as an earphone device is attached to the user's auricles.

Figure 5B is a cross-sectional view showing the state in which the electro-acoustic transducer arranged as the earphone device is attached to the user's auricles.

Figure 6A is a side view showing another example of the state in which the electro-acoustic transducer arranged as the earphone device is attached to the user's auricles.

Figure 6B is a cross-sectional view showing another example of the state in which the electro-acoustic transducer arranged as the earphone device is attached to the user's auricles.

Figure 7 is a perspective view showing still another example of the state in which the electro-acoustic transducer arranged as an earphone device is attached to the user's auricles.

Figure 8 is a perspective view showing the electro-acoustic transducer arranged as the headphone device.

Figure 9 is a perspective view showing still another example of construction of the electro-acoustic transducer.

Figure 10 is a diagrammatic perspective view showing the construction of the sound reproducing system of the present invention.

Figure 11 is a circuit diagram showing the construction in the above sound reproducing system whereby the low frequency component of the acoustic signals may be supplied to the electro-acoustic transducer.

Figure 12 is a chart showing frequency characteristics of the amplifier supplying the low frequency component of the acoustic signals to the electro-acoustic transducer shown in figure 11 and frequency characteristics of the reproduced sound of the transducer.

Figure 13 is a circuit diagram showing another example of construction of supplying the low frequency component of the acoustic signals to the electro-acoustic transducer.

Figure 14 is a perspective view showing the construction of supporting the sound reproducing apparatus of the sound reproducing system by the listener's head.

Figure 15 is a side view showing the construction in which a sound guide tube is provided in the sound reproducing apparatus supported by the listener's head in the sound reproducing system.

Figure 16 is a cross-sectional view showing another example of construction of the electro-acoustic transducer in the sound reproducing system.

Figure 17 is an equivalent acoustic circuit diagram showing acoustic characteristics of the electro-acoustic transducer shown in figure 16.

Figure 18 is a cross-sectional view showing still another example of construction of the electro-acoustic transducer in the sound reproducing system.

Figure 19 is a side view showing another example of construction of sound guide tube of the electro-acoustic transducers of various types.

Figure 20 is a cross-sectional view showing the construction using the headphone device attached to the user's auricle as the sound reproducing device in the above sound reproduc-

ing system.

Figure 21 is a cross-sectional view showing the construction of the hermetically sealed headphone device used as the sound reproducing apparatus of the sound reproducing system.

By referring to the drawings, certain preferred embodiments of the present invention will be explained in detail.

Figures 1 to 4 illustrate an embodiment of an electro-acoustic transducer which is constructed as an earphone device attached to auricles.

The earphone device shown in figure 1 includes a housing or cabinet 1 and a sound reproducing unit 2 which is an electro-acoustic transducer unit housed within the cabinet 1.

The sound reproducing unit 2 includes a diaphragm and a magnetic circuit. A voice coil is mounted on the diaphragm so as to lie in the magnetic path of the magnetic circuit. That is, with the present sound reproducing unit 2, when the electrical signal which is the driving signal is supplied to the voice coil via feeder 2a, the voice coil is driven and offset in the magnetic path of the magnetic circuit. The offsetting of the voice coil is transmitted to the diaphragm which then radiates the reproduced sound towards the front and rear sides.

The cabinet 1 is formed of synthetic resin, for example, and is formed for accommodating and supporting the sound reproducing unit 2. The cabinet 1 has an opening 1a whereby the front side functions as the sound radiating side of the sound reproducing unit 2 which faces to the outside. The cabinet 1 accommodates and supports the sound reproducing unit 2 with the front side of the sound reproducing unit 2 facing outwards via opening 1a.

The feeder (electrical connecting lead) 2a is led out of the cabinet 1 by means of a feeder outlet 1c provided in the cabinet 1.

The cabinet 1 is provided with a sound guide tube 3 establishing communication between the inside and the outside of the cabinet 1. Thus the cabinet 1 is provided with a sound conducting opening 1b situated at the lateral side of the sound reproducing unit 2, the sound guide tube 3 in the form of a hollow cylinder is provided in alignment with the opening 1b. This sound guide tube 3 is formed integrally with the cabinet 1 and with a predetermined length so as to project away from the cabinet 1. The terminal end 3a, functioning as the sound radiating end, is bent over so as to face in the same direction as the unit 2 and is opened as the sound radiating opening 3b.

Thus the sound radiated from the rear side of the sound reproducing unit 2 into the inside of the cabinet 1 propagates from the inside of the cabinet by way of the sound conducting opening 1b into the inside of the sound guide tube 3 so as to be radiated outwards via sound radiating opening 3b of the sound guide tube 3.

The distal end 3a of the sound guide tube 3 has an outside diameter, as shown by arrow d in figure 1, which is less than the inside diameter of the external auditory miatus E shown by arrow e in figure 1, so that the distal end 3a may be inserted into the external auditory miatus E without fully closing the external auditory miatus E to provide an interstice large enough to permit sound propagation between it and the inner wall of the external auditory miatus E. Meanwhile, the inside diameter of the external auditory miatus E of a human is usually 7 to 9 mm. The sound guide tube 3 has its distal portion 3c bent accurately in about 90° direction, so that device, to the user's auricles, the sound radiating opening 3b is directed to the inside of the external auditory miatus E.

When the above described earphone device is in use, the distal end 3a of the sound guide tube 3 is inserted into the external auditory miatus E, as shown in figure 1. That is, this earphone device is supported by a supporting member, as later described, so that the sound radiated from the sound radiating opening 3b at the distal end 3a of the sound guide tube inserted into the external auditory miatus E will reach the tympanic membrane, not shown, after propagation through the inside of the external auditory miatus E.

This earphone device allows the sound from the sound reproducing unit 2 to reach the tympanic membrane via the external auditory miatus E without closing off the external auditory miatus E. Hence, with the present earphone device, the sound may be reproduced without impeding the audibility of external sounds.

Figure 2 shows an equivalent acoustic circuit showing acoustic characteristics of the earphone device. An equivalent mass Md for the sound reproducing unit 2, a compliance Cd and an acoustic resistance Rd are connected in series and a compliance Cb within the cabinet 1 is connected to the series connection of the equivalent means Md, compliance Cd and the acoustic resistance Rd to form a closed loop. One of the junctions between the compliance Cb on one hand and the equivalent mass Md, compliance Cd and the acoustic resistance Rd, on the other, is connected to an acoustic circuit ϵ within the external acoustic miatus E via the equivalent mass Mb of the air in the sound guide tube 3. The other of the junctions between the compliance Cb on one hand and the equivalent mass Md, acoustic resistance Rd and compliance Cd on the other, is connected directly to the acoustic circuit ϵ of the external acoustic miatus E. the acoustic circuit ϵ in the external acoustic miatus E forms a closed loop consisting of the equivalent mass Me within the external auditory miatus E.

compliance Ce and acoustic resistance Re. The junction between the compliance Ce and the acoustic resistance Re is connected to an equivalent mass Mb of the air in the sound guide tube 3. The junction between the compliance Ce and the equivalent mass Me is connected to the other B of the junctions between equivalents mass Md, compliance Cd and acoustic resistance Rd on one hand and compliance Cb on the other.

With the above acoustic circuit, the resonant frequency f_0 of the earphone device f_c is given by

$$f_0 = 1/(2\pi \sqrt{CMd + Mb)\,Cd} \quad (1)$$

which is lower than the resonance frequency of the sound reproducing unit 2 alone. Hence, with the above earphone device, optimum sound reproduction may be achieved over a wide frequency range including the low frequency range.

The frequency response of the reproduced sound by the sound reproducing unit 2 alone exhibits a resonance peak at about 2 kHz, as shown in figure 3. In order to reduce the effects of this resonance peak, the above sound signals are supplied via a correction circuit 5 to the sound reproducing unit 2. As shown in figure 4, this correction circuit 5 has a series circuit of first and second capacitors 6 and 7 between one of the output ends 5b of the signal source 5a and the one input end of the sound reproducing unit 2, and first and second resistances 8 and 9 are connected in series so as to be in parallel with the capacitors 6 and 7. The junction between the capacitors 6 and 7 is connected via third resistor 10 to the other output end 5c of the signal source 5a connected to the other input end of the sound reproducing unit 2. The junction between the first resistor 8 and the second resistor 9 is connected via third capacitor 11 to the other output end 5c of the signal source 5a.

By supplying the above acoustic signals by way of the above described correction circuit 5 to the sound reproducing unit 2, the sound may be reproduced with a smoother frequency characteristic which is affected to a lesser extent by resonant peaks.

The electro-acoustic transducer of the present invention may be constructed so that a pair of the above described earphone devices are adapted to be attached to the user's auricles and are used for left and right ears to perform stereophonic sound reproduction.

On the other hand, the sound reproducing unit of the electro-acoustic transducer of the present invention may be accommodated in and supported by the cabinet 1 with the rear side facing outwards by way of the opening 1a and the front side facing the inner side of the cabinet 1. In this case, the sound radiated from the front side of the sound reproducing unit 2 may be guided by the sound guide tube 3 to reach the external auditory miatus E.

The electro-acoustic transducer of the present invention, formed as an earphone device attached to the user's auricles when in use, may also be so arranged and constructed that, as shown in figures 5A and 5B, a protuberance 4a is provided as the supporting member at the foremost part 3c of the sound guide tube 3 and the forward side 3c of the sound guide tube 3 and the forward side 3c of the sound guide tube 3 is supported in a cavity of the concha D which is a recessed part of the auricle C. That is, with the present earphone device, when the distal side 3c of the sound guide tube 3 is inserted into the cavity of the concha D, with the proximal side of the ear guide tube 3 directing downwards, the projection 4a is supported in abutment with the tragus F and the antitragus J in the lower region of the auricular recess D. The sound guide tube 3 depends from an intertragic notch K between the tragus F and the antitragus J, and is supported in abutment with the outer surface of the otorrhea, a portion of the auricle C, at a position below the intertragic notch K.

With the projection 4a supported in abutment with the tragus F and the antitragus J, and with the sound guide tube 3 supported in abutment with the otorrhea L, the distal side 3c of the sound guide tube 3 is held within the cavity of the concha D, and the distal end 3a of the sound guide tube 3 is introduced into the external auditory miatus E, as shown in figure 5B. With the earphone device, since the point of abutment of the sound guide tube 3 by the otorrhea L is below the support point supporting the projection 4a, rotation in the direction shown by arrow X in figure 5B, with the abutting support point between the tragus F and J the antitragus as the centre of rotation, which is the direction of falling of the projection 4a from the cavity of the concha D, is inhibited, to guarantee safe and positive support of the earphone device by the auricle C.

With the earphone device, a toroidal member 4b may also be provided as the supporting member at the distal side 3c of the sound guide tube 3, as shown in figures 6A and 6B, so that the distal side 3c of the sound guide tube 3 may be maintained in the cavity of the concha D by the toroidal supporting member 4b. That is, with the present earphone device, when the distal side 3c of the sound guide tube 3 is inserted into the cavity of the concha D, with the proximal side of the round guide tube 3 directing downwards the toroidal member 4b is supported in abutment with the tragus and the antitragus J in the cavity of the concha D. The rear peripheral surface of the toroidal member 4b, facing to the outside of the auricle C on introducing the toroidal member 4b into the cavity of the concha D, is formed as a

tapered inclined portion 4d to assure optimum abutment by the tragus F and the antitragus J. The sound guide tube 3 is adapted to depend downwards via the intertragic notch K between the tragus F and the antitragus J and is supported in abutment with the outer lateral surface of the otorrhea L.

When the toroidal member 4b is thus supported in abutment with the tragus F and the antitragus J, and the sound guide tube 3 is supported in abutment with the otorrhea L, the distal side 3c of the sound guide tube 3 is held within the cavity of the concha D, as shown in figure 6B, and the distal end 3a of the sound guide tube 3 is inserted into the external auditory miatus E, which simultaneously faces outwards by way of a central through-hole 4c in the toroidal member 4b. With the present earphone device, similarly to the earphone device shown in figure 5B, the abutting point of the sound guide tube 3 on the otorrhea L and that of the toroidal member 4b on the tragus F and the antitragus J acts to inhibit rotation of the toroidal member 4b in the direction of falling of the toroidal member from the cavity of the concha D as shown by an arrow x in figure 6B to guarantee safe and positive holding of the earphone device by the auricle C.

Meanwhile, with the earphone device shown in figures 5A, 5B, 6A and 6B, the sound tube 3 is adapted to communicate with the cabinet 1 at the lateral surface on the proximal side, and the feeder outlet 1c is provided on the proximal side.

The earphone device may also be constructed that, as shown in figure 7, an arm-shaped ear hanger 13, bent as a supporting member, is provided at the outward side of the cabinet I, and the ear hanger 13 is engaged and supported on the upper side of the outer lateral side of the auricle C. With this earphone device, when the ear hanger 13 is engaged with and supported by the auricle C, the distal side 3a of the sound guide tube 3 is inserted into the external auditory miatus E.

The electro-acoustic transducer of the present invention may also be arranged as to be attached to the user's head. Thus, as shown in figure 8, a pair of the above described earphone devices are attached to both sides of a hair band 12 adapted to conform substantially to the user's head. Such headphone device is used with the hairband 12 supported by the user's head and the distal sides of the sound guide tubes 3 of the earphone devices inserted into external auditory miatuses of the user's left and right ears. The headphone device shown in figure 8 has a pair of the sound reproducing units 2 to perform stereophonic reproduction.

The electro-acoustic transducer of the present invention may also be constructed as shown in figure 9 wherein the cabinet 1 is provided on the hairband 12 and two sound guide tubes 3l, 3r for left and right ears are provided on the cabinet 1. The sound guide tubes 3l, 3r are adapted to project on both sides of the hairband 12. This electro-acoustic transducer is used with the hairband 12 being supported on the user's head and the distal sides 3a of the sound guide tubes 3l, 3r, being inserted into the external auditory miatuses E of the user's left and right ears. With the electro-acoustic transducer, the sound reproduced by the sound reproducing unit accommodated in and supported by the cabinet 1 is propagated through the sound guide tubes 3l, 3r to reach the external auditory miatuses E of the left and right ears.

The sound reproducing system according to the present invention shown in figure 10 is comprised of a headphone device 14 of the type attached to the user's auricles, which is provided with a pair of the earphone devices shown in figure 1 to constitute an electro-acoustic transducer, and left and right speaker devices 15l, 15r functioning as sound reproducing devices.

Each of the speaker devices 15l, 15r is provided with a speaker unit 15a having a magnetic circuit and a diaphragm and a speaker cabinet 15b accommodating and supporting the speaker unit 15a with the sound radiating side facing outwards. When the sound signals are supplied to the speaker devices 15l, 15r, these devices 15l, 15r convert the sound signals into vibrations of the diaphragm of the speaker unit 15a to reproduce the sound. The speaker units 15l, 15r are positioned on the left and right forward sides of the listener 17 with the sound radiating side facing the listener 17.

In order that only the low frequency component of the acoustic signals supplied to the speaker devices 15l, 15r will be supplied to the headphone device 14, the above mentioned acoustic signals are supplied to the headphone device 14 via amplifier 16, as shown in figure 11. The amplification factor-frequency characteristics of the amplifier 16 are approximately zero in the range above about 1 kHz, as shown at G in figure 12 and, in the range below about 1 kHz, the amplification factor higher.

The headphone device 14, supplied with the electrical signals by way of the amplifier 16 having such amplification factor-frequency characteristics, performs sound reproduction with the frequency characteristics in which the sound pressure is raised in the frequency range of 20 to 100 Hz.

With the above described sound reproducing system of the present invention, the drive signals are reproduced as the sound by the speaker devices 15l, 15r, while the low frequency component of the drive signals is reproduced by the headphone device. Since the headphone device 14 causes the reproduced sound to reach the tympanic membrane of the listener 17 without obstruct-

ing the external acoustic miatus E of the listener 17, the listener 17 may hear the sound reproduced by the speaker device 15l, 15r and the sound reproduced by the headphone device 14 simultaneously.

Hence, the above described sound reproducing system permits the size of the speaker cabinet 15b or the speaker unit 15a constituting the speaker devices 15l, 15r to be reduced and the reduction of output of these speaker devices 15l, 15r in the low frequency range is compensated by the sound reproduction in the low frequency range by means of the headphone device 14. Thus, with the present sound reproducing system, the sound from the speaker device 15l, 15r and the sound from the headphone device 14 cooperate to realise satisfactory sound reproduction over a wide frequency range including the low frequency range.

Meanwhile, with the present sound reproducing system, the directionality and fixity of items making up the perceived sound-stage is largely determined by sounds in the low to high frequency range reproduced by the speaker devices 15l, 15r. Sound within the low frequency range which is reproduced by the headphone device 14 does not essentially affect the directionality and fixity of the reproduced sound.

The amplifier 16 may also be so constructed that its characteristics can be switched between the amplification frequency characteristics emphasising the above mentioned low frequency range and a substantially flat frequency response across the entire frequency range. When using the flat-respect setting of the amplifier 16, the headphone device 14 reproduces the sound over the entire frequency range, so that satisfactory sound reproduction may be achieved without using the speaker devices 15l, 15r.

In order that only the low frequency component of the sound signal will be supplied to the headphone device 14, the sound signal may be supplied to the headphone device 14 via a passive network type electrical circuit 18, as shown in figure 13. This passive network type electrical circuit 18 includes a plurality of coils 20a, 20b, 20c interposed between one output 19a of a signal source 19 and an input of the sound reproducing unit 2 of the headphone device 14. These coils 20a, 20b, 20c are connected in series with one another. Capacitors 21a, 21b, 21c are interposed between junctions between the coils 20a, 20b, 20c and the other output 19b of the signal source 19 connected to the other input of the sound reproducing unit 2.

The sound signals supplied to the headphone device 14 via passive network type electrical circuit 18 are supplied to the headphone device 14 after damping which is applied more strongly to higher frequency components. The degree of damping may be determined by suitably setting the inductance values of the coils 20a, 20b, 20c and the reactance values of the capacitors 21a, 21b, 21c and may be represented by how much the level of the sound signal of the double frequency is damped with respect to the sound signals of a given frequency, such as 6 dB/Oct or 12 dB/Oct.

The acoustic circuit for the headphone device 14 is shown in figure 2 wherein the equivalent mass Mb of the air in the sound guide tube 3 is connected to the acoustic circuit for the sound reproducing unit 2. Therefore, the larger the equivalent mass Mb of the air within the sound guide tube 3, the lower is the resonance frequency f_0 of the headphone device 14, so that more satisfactory reproduction of the sound signal of the low frequency range may be realised by the headphone device 14.

The sound reproducing system according to the present invention is not limited to constructions in which sound reproduction for only the low frequency range may be made by the headphone device 14 but so-called surround sound may be reproduced by the headphone device 14. That is, the sound signals supplied to the speaker devices 15l, 15r are supplied via a so-called surround sound circuit to the headphone device 14. This surround circuit outputs the sound signal after predetermined delaying and damping.

With the above described sound reproducing system, the sound reproduced by the speaker devices 15l, 15r and the sound reproduced by the headphone device 14 cooperate to reproduce the sound with so-called concert-hall presence, that is, simultaneously with the reverberating and residual sound components.

The sound reproducing system of the present invention may be constructed as shown in figure 14 wherein the speaker devices 15l, 15r may be supported by the listener's head 17.

With the sound reproducing system, shown in figure 14 the speaker devices 15l, 15r are supported at the forward left and forward right sides of the listener 17, by the hairband 12 and a pair of speaker supporting arms 22 projectingly supported by the hairband 12, with the sound radiating side facing the listener 17. The headphone device 14 is worn by the listener 17 as is the above mentioned sound reproducing system.

With the present sound reproducing system, since the speaker devices 15l, 15r governing the stationary image-position sensation of the reproduced sound are supported by the listener's head 17 and the speaker devices 15l, 15r are moved to follow the listener's head when the listener 17 moves his head, sound reproduction may be performed satisfactorily without altering the perceived sound stage.

On the other hand, with the above described sound reproducing system in which the speaker devices 15l, 15r are supported by the listener's head, the sound guide tube 3 may be provided on the speaker cabinet 15b of the speaker devices 15l, 15r, without using the headphone device 14, as shown in figure 15.

That is, with the present sound reproducing system, the sound guide tube 3 similar to that provided on the cabinet 1 of the headphone device 14 is provided on the speaker cabinet 15b. This sound guide tube 3 is so constructed that the sound radiated from the rear surface of the speaker cabinet 15b towards the inner side of the speaker cabinet 15b will be conducted outwards via sound guide opening 15c provided in the speaker cabinet 15b and radiated via sound radiating opening 3b at the distal end 3a so as to reach the external auditory miatus E of the listener 17. That is, with the present sound reproducing system, the sound radiated by the speaker unit 15a towards the front side proves to be the sound reproduced by the sound reproducing device, while the sound radiated by the speaker unit 15a is equivalent to the sound reproduced by the electro-acoustic transducer.

The above described sound reproducing system is so designed that the resonant frequency in the speaker cabinet 15b and in the sound guide tube 3 becomes lower than the resonant frequency in the speaker unit 15a, and that the low frequency component of the sound radiated by the speaker unit 15a is conducted more efficiently in the sound guide tube 3. Thus, with the present sound reproducing system, even if the sound pressure of the low frequency component of the reproduced sound radiated by the speaker devices 15l, 15r towards the front side is insufficient, the low range frequency component of the sound radiated towards the rear side of the speaker unit 15a are conducted by the sound guide tube 3 to the external auditory miatus E of the listener 17 to realize satisfactory sound reproduction.

In the sound reproducing system of the present invention, when the reproduction of the low frequency component only of the sound is to be performed by the headphone device 14 the headphone device 14 may be replaced by a headphone device or an earphone device show in figures 5A to 9. Since the sound of the low frequency range does not affect the positional stability of the reproduced sound, sound reproduction may be achieved satisfactorily when the sound of the low frequency range is supplied only to one ear.

As the electro-acoustic transducer constituting the sound reproducing system of the present invention, a variety of transducers constructed for satisfactorily reproducing low frequency sound may be used, in addition to the above described headphone device 14, headphone device or earphone devices shown in figures 5A to 9.

As the earphone device constituting the headphone device 14, there may be used a device in which, as shown in figure 16, a partition wall 24 having a duct 23 in the cabinet 1 of the earphone device shown in figure 1 may be provided and this earphone device may be constructed as the so-called double bus ref (bass reflex) type. With this earphone device, the inside of the cabinet 1 is divided by the partition wall 24 into a first air chamber 25 on the side of the sound reproducing unit 2 and a second air chamber 26 on the side of the sound guide opening 1b. These first and second air chambers 25, 26 communicate with each other by the above duct 23 provided in the partition wall 24.

With the above described earphone device, the sound radiated towards the rear side of the sound reproducing unit 2 is radiated into the first air chamber 25 so as to be guided via duct 23 into the second air chamber 26. The sound guided into the second air chamber 26 is guided outwards via sound conducting opening 1b and the sound guide tube 3.

In an equivalent acoustic circuit of the above described earphone device, shown in figure 17, the equivalent mass Md, compliance Cd and the acoustic resistance Rd of the sound reproducing unit 2 are connected in series and a compliance C_1 in the first air chamber 25 is connected to the series circuit to form a closed loop. One of the junctions between the equivalent mass Md, compliance Cd and the acoustic resistance Rd shown in figure 17A is connected to an acoustic circuit ϵ of the external auditory miatus E by way of the air equivalent mass M_1 in the duct 23 and the air equivalent mass Mb in the sound guide tube 3. The equivalent mass M_1 and the equivalent mass Mb are connected in series with each other. The other junction between the equivalent mass Md, compliance Cd and the acoustic resistance Rd on one hand the compliance C_1 on the other, shown at B in figure 17, is connected to the acoustic circuit ϵ of the external auditory miatus E. A compliance C_2 in the second air chamber 26 is interposed and connected between the junction between the equivalent mass M_1 of the air in the duct 23 and the equivalent mass Mb of the air in the sound guide tube 3 and the other junction between the compliance C_1 on one hand and the equivalent mass Md, compliance Cd and the acoustic resistance Rd on the other, shown at B in figure 17.

In the acoustic circuit ϵ of the external auditory miatus E, the equivalent mass Me in the external auditory miatus E, compliance Ce and the acoustic resistance Re constitute a closed loop. The junction between the compliance Ce and the acoustic

resistance Re is connected to the equivalent mass Mb in the sound guide tube 3. The junction between the compliance Ce and the equivalent mass Me is connected to the other junction between the equivalent mass Md, compliance Cd and the acoustic resistance Rd, shown at B in figure 17.

With the above described earphone device, by the acoustic circuit shown in figure 17, the resonant frequency f_o of the earphone device may become the lower, the larger the sum of the equivalent mass M_1 of the air in the duct 23 and the equivalent mass Mb of the air in the sound guide tube 3. That is, with the present earphone device, the resonant frequency f_o may be made lower by an amount corresponding to the equivalent mass M_1 of the air in the duct 23, as compared to the earphone device shown in figure 1, so that sound reproduction of the low frequency range may be performed satisfactorily.

As the earphone device constituting the headphone device 14, such transducer may be employed in which, as shown in figure 18, the sound guide tube 3 or of the earphone device show in figure 1 is divided into plural sound guide sections 28a, 28b by a partition wall 27 formed along the axis of the sound guide tube 3.

That is, with the sound guide tube 3 of the present earphone device, the sound guide sections 28a, 28b defined by the partition wall 27 may have different inside diameters or lengths, while they are so adapted that the equivalent masses in the sound guide sections 28a, 28b are approximately equal to one another. Hence, with the present earphone device, it becomes possible to prevent resonance from being produced along the length of the sound guide tube 3 to realize optimum sound reproduction in the low frequency range.

In the earphone device constituting the headphone device 14, a hermetic sealing member 29 formed of an air permeable material such as urethane may be provided for surrounding the outer peripheral surface of the distal side 3c of the sound guide tube 3, as shown in figure 19.

In such earphone device in which the sealing member 29 is provided on the outer peripheral surface at the distal end 3c of the sound guide tube 3, the extent of hermetic sealing extent in the sound guide tube 3 and the external auditory miatus E is improved to increase the sound pressure of the reproduced sound in the low frequency range.

Meanwhile, since the sealing member 29 exhibits air permeability, it does not obstruct the hearing of the sound reproduced by the speaker devices 15l, 15r or the exterior sound. The sealing member 29 may be made detachable with respect to the sound guide tube 3.

As the sound reproducing system constituting the sound reproducing system of the present invention, headphone devices designed for performing sound reproduction over the entire frequency range from the low to the high range may also be used besides the above mentioned speaker devices 15l, 15r.

Thus, as shown in figure 20, this sound reproducing system is comprised of a headphone device of the type attached to the user's auricle, which is supplied with acoustic signals to reproduce the sound, and an electro-acoustic transducer 34 adapted for reproducing at least the low frequency component of the acoustic signals supplied by means of the amplifier 16 or the passive network 18. As the electro-acoustic transducer 34, the earphone devices shown in figures 1, 5A to 9, 16 or 18, or a headphone device making use of a pair of such earphone devices, are used.

The headphone device attached to the user's auricles 30 is adapted for supporting a pair of sound reproducing units 31, adapted for converting acoustic signals into sound, in a confronting relation at the inlets to both external auditory miatuses E. That is, the sound reproducing units 31 are accommodated in and supported by a headphone cabinet 32, as shown in figure 20, with the sound radiating side facing outwards by means of the sound radiating opening 32a. This headphone cabinet 32 is accommodated in the cavity of the concha D, which is the recess in the auricle C, with the sound radiating side of the sound reproducing unit 31 facing the inlet to the external auditory miatus E, and is supported by the tragus and the antitragus. An electrical lead 31a supplying the drive signal to the sound reproducing unit 31 is taken out by way of a cord guide section 32c extended from the headphone cabinet 32 and by way of a feeder outlet 32c provided at the foremost part of the cord guide section 32c.

The headphone cabinet 32 is provided with a sound guide extension tube 33 for establishing communication between the vicinity of the periphery of the sound reproducing unit 31, which is the sound radiating side of the sound reproducing unit 31, and the back side of the headphone cabinet 32 facing the sound radiating side. That is, the sound guide extension tube 33 is formed as a tube opened at both ends and made integral with the headphone cabinet 32, within this headphone cabinet 32, so that one end opening 33a faces to the front side from the vicinity of the periphery of the sound reproducing unit 31 and the other end opening 33b faces the rear side from the vicinity of the centre on the rear surface of the headphone cabinet 32.

The distal end 3a of the sound guide tube 3 of the electro-acoustic transducer 34 may be detachably inserted and engaged into the other end

opening 33b of the sound guide extension tube 33. That is, the sound radiated from the rear surface of the sound reproducing unit 2 of the electro-acoustic transducer 34 into the inside of the cabinet 1 of the electro-acoustic transducer 34 is conducted into the inside of the sound guide extension tube 33 by way of the sound guide tube 3, the sound radiating opening 3b and the other end opening 33b of the sound guide extension tube 33. The sound thus conducted into the sound guide extension tube 33 is propagated in the extension tube 33 so as to be radiated at one end opening 33a facing the front side. The one end opening 33a of the sound guide extension tube 33 faces the inlet of the external auditory miatus E, as does the acoustic transducer unit 31 of the headphone device 30 attached to the user's auricle, so that the sound radiated from the end opening 33a reaches the inside of the external auditory miatus E.

With the above described sound reproducing system, the sound is reproduced by the headphone device attached to the user's auricle 30 over the entire frequency range. Even if the low frequency component of the sound reproduced by the headphone device attached to the user's auricle 30 has an insufficient sound pressure, the sound of the low frequency range is reproduced by the electro-acoustic transducer 34 to reach the external auditory miatus E. That is, the sound reproduced by the headphone device attached to the user's auricle 30 and the sound reproduced by the electro-acoustic transducer 34 cooperate with each other to effect satisfactory sound reproduction.

On the other hand, when employing the headphone device as the sound reproducing apparatus constituting the sound reproducing system of the present invention, the headphone device attached to the user's head, that is the so-called hermetically sealed headphone device, may be employed.

The head attachment type headphone device 35 is so constructed that a pair of sound reproducing units 36 for converting acoustic signals into sound are supported in a confronting relation to the entrance to both external acoustic miatuses E. That is, as shown in figure 21, the sound reproducing unit 36 is accommodated in the associated headphone cabinet 37, with the sound radiating surface facing outwards by way of the sound radiating opening 37a. These headphone cabinets 37 are attached to both ends of the headband 38 and, with the headband 38 supported by the listener's head, the headphone cabinets 37 are supported in abutment with the auricles C so that the sound radiating surface of the sound reproducing unit 36 faces the inlet to the external acoustic miatus E. On the perimeter of the headphone cabinet 37 abutting on the auricle C is mounted an annular buffer member 39 of urethane or rubber. The lead 36a for supplying drive signals to the sound reproducing unit 36 is extracted outwards by a feeder outlet 37b provided at the headphone cabinet 37.

The headphone cabinet 37 is provided with a sound guide extension tube 40 for establishing communication between the vicinity of the perimeter of the sound reproducing unit 36 on the front side or the sound radiating side of the sound reproducing unit 36 and the rear surface of the headphone cabinet 37 facing the sound radiating side, as in the case of the above mentioned headphone attached to the user's auricle 30. The sound guide extension tube 40 is formed in the headphone cabinet 37 as a tube which is opened on both sides and formed integrally with the headphone cabinet 37, with one end opening 40a facing forwards from the vicinity of the periphery of the sound reproducing unit 36 and with the other end opening 40b facing rearwards from about the centre of the rear surface of the headphone cabinet 37.

The other end opening 40b of the sound guide extension tube 40 is so formed that the distal end 3a of the sound guide end 3 of the electro-acoustic transducer 34 may be detachably inserted and engaged therein. That is, the sound radiated from the rear side of the sound reproducing unit 2 of the electro-acoustic transducer 34 is adapted to be transmitted into the sound guide extension tube 40 by way of the sound guide tube 3, the sound radiating opening 3b and the other end opening 40b of the sound guide extension tube 40. The sound transmitted into the sound guide extension tube 40 is propagated within the sound guide extension tube 40 so as to be radiated at the one end opening 40a facing the front side. The one end opening 33a of the sound guide extension tube 40 faces the inlet to the external auditory miatus E, as does the acoustic transducer unit 36 of the hermetically sealed headphone device 35, so that the sound radiated from one end opening 40a may reach the external acoustic miatus E.

With the above described sound reproducing system, the sound may be reproduced over the full frequency range by the above mentioned hermetically sealed headphone device 35. Even if the low frequency component of the sound reproduced by this hermetically sealed headphone device 35 has only an insufficient sound pressure, the sound of the low frequency range is reproduced by the electro-acoustic transducer 345 so as to reach the external auditory miatus E. That is, the sound reproduced by the hermetically sealed headphone device 35 and the sound reproduced by the electro-acoustic transducer 34 cooperated with each other to effect satisfactory sound reproduction.

With the above described electro-acoustic transducer of the present invention, the sound guide

tube by which the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet is conducted out of the cabinet is of a lesser diameter than the external auditory miatus, at least at the sound radiating end, so as to be inserted into the external auditory miatus. For this reason, it becomes possible for the electro-acoustic transducer to conduct the sound through the external auditory miatus without obstructing the external auditory miatus.

Hence, with the present electro-acoustic transducer, no standing waves are produced in the space between the tympanic membrane of the listener and the transducer unit, while the extraneous sound may be propagated into the external auditory miatus by way of the space between the inner wall of the external auditory miatus and the outer periphery of the sound guide tube.

Thus the present invention may provide an electro-acoustic transducer which may be applied advantageously to, for example, an earphone device or a headphone device, and which may reproduce the sound without an oppressed feeling.

In addition, with the sound reproducing system of the present invention, the electro-acoustic transducer is supplied with drive signals and transduces the drive signals into sound to reproduce the sound by a sound reproducing device, and at least the low frequency component of the acoustic signal supplied to the sound reproducing device is converted into sound. Thus the sound is radiated into the external auditory miatus, without closing off the external auditory miatus, by means of a sound guide tube of a lesser diameter than the external auditory miatus, so that the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet may be conducted towards outside of the cabinet and at least the sound radiating side may be inserted into the external auditory miatus.

Hence, with the present sound reproducing system, both the sound reproduced by the sound reproducing device and the sound reproduced by the sound reproducing unit of the headphone device may be heard simultaneously.

Thus, even if the low frequency component of the sound reproduced by the sound reproducing device has insufficient sound pressure, this sound may reach the external auditory miatus E. Thus the sound reproduced by the hermetically sealed headphone device 35 and the sound reproduced by the electro-acoustic transducer cooperate to effect satisfactory sound reproduction.

With the above described electro-acoustic transducer of the present invention, the sound guide tube for conducting the sound radiated from the electro-acoustic transducer unit accommodated in the cabinet has at least its sound radiating end of a lesser diameter than the external auditory miatus so that the sound radiating end may be inserted into the external auditory miatus. Thus it is possible with the present electro-acoustic transducer to conduct the sound into the external auditory miatus without occluding it.

Thus, with the present electro-acoustic transducer, no standing waves are produced between the listener's tympanic membrane and the electro-acoustic transducer unit, while extraneous sound may be propagated between the inner wall of the external auditory miatus and the outer peripheral surface of the sound guide tube.

Thus the present invention provides an electro-acoustic transducer which may be advantageously applied to, for example, an earphone device or a headphone device and with which the sound may be reproduced without causing an oppressed feeling or a feeling as if the sound source were situated stationarily within the listener's head.

With the sound reproducing system according to the present invention, the sound reproducing device is adapted to be supplied with electrical signals and to transduce these signals into sound for reproduction thereof, while the electro-acoustic transducer is adapted to transduce at least the low frequency component of the signals supplied to the sound reproducing device into sound. The electro-acoustic transducer radiates the sound into the external auditory miatus without stopping it by means of a sound guide tube which is of a lesser diameter than the external auditory miatus in order to conduct the sound radiated from the electro-acoustic unit accommodated in the cabinet towards the outside of the cabinet and to permit at least the sound radiating end to be inserted into the external auditory miatus.

Hence, with the present sound reproducing system both the sound reproduced by the sound reproducing device and the sound reproduced by the sound reproducing unit of the headphone device may be heard simultaneously.

Therefore, even if the low frequency component of the sound reproduced by the sound reproducing device has insufficient sound pressure, this sound is reinforced by the sound reproduced by the electro-acoustic transducer to achieve satisfactory sound reproduction.

It is noted that, since positional stability of the reproduced sound is determined by sound in the medium to high frequency range reproduced by the sound reproducing device, this is hardly affected by the sound in the low frequency range even if the sound in the low frequency range is radiated into the external auditory miatus.

Thus the present invention provides a sound reproducing system in which the sound may be reproduced satisfactorily over a wide frequency range, encompassing the low frequency range,

without increasing the size of the system or inconveniencing neighbours.

Claims

1. An electro-acoustic transducer comprising
an electro-acoustic transducer accommodated in a cabinet, and
a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said cabinet,
said sound guide tube being of a lesser diameter than the external acoustic miatus to allow at least the sound radiating end of the sound guide tube to be introduced into the external auditory miatus

2. the electro-acoustic transducer according to claim 1, wherein said cabinet is formed for covering the rear side of said electro-acoustic transducer unit.

3. The electro-acoustic transducer according to claim 2, wherein said sound conducting tube is substantially L-shaped and has it end opposite to said sound radiating and connected to a sound conducting opening provided on the lateral side of said cabinet.

4. The electro-acoustic transducer according to claim 1, 2 or 3 further comprising supporting means for supporting one of said transducer unit or said sound guide tube such that the sound radiating end of said sound guide tube is at a predetermined position within the external auditory miatus.

5. The electro-acoustic transducer according to claim 4, wherein said supporting means comprises at least one projection provided at the distal side of said sound conducting tube and adapted to be engaged with an auricular recess.

6. The electro-acoustic transducer according to claim 4, wherein said supporting means comprises a toroidal member provided at the distal end of said sound guide tube and adapted for being held in the cavity of the concha.

7. The electro-acoustic transducer according to claim 4, wherein said supporting means comprises an ear hanger provided outside the cabinet and engaged with the upper side of the outer periphery of said cabinet.

8. The electro-acoustic transducer according to claim 4, wherein said supporting means comprises a head band.

9. The electro-acoustic transducer according to claim 8, wherein said cabinet is provided at an upper end portion of said head band and a pair of said sound guide tubes are provided at said cabinet.

10. The electro-acoustic transducer according to anyone of the preceding claims, wherein a hermetic sealing member formed of an air permeable material is provided at the sound radiating end of said sound guide tube.

11. The electro-acoustic transducer according to anyone of the preceding claims, wherein acoustic signals supplied to said transducer unit are supplied thereto by way of a compensation circuit for compensating frequency resonance peaks generated in said transducer unit.

12. A sound reproducing system comprising
a sound reproducing apparatus for receiving electrical signals and transducing them into sound, and
an electro-acoustic transducer including an electro-acoustic transducer unit accommodated in a cabinet, and a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said cabinet,
said sound guide tube having at least the sound radiating end of a lesser diameter than the external auditory miatus to permit said sound radiating end to be introduced into the external auditory miatus,
said electro-acoustic transducer being adapted for reproducing at least the low-frequency component of the frequency range of the acoustic signal of the sound reproduced by said sound reproducing apparatus.

13. The electro-acoustic transducer according to claim 12, wherein at least the low frequency component of the acoustic signals supplied to said sound reproducing apparatus is supplied to said electro-acoustic transducer.

14. The system according to claim 12, further comprising amplifier means for amplifying the low frequency component of the acoustic signal supplied to said sound reproducing apparatus.

15. The system according to claim 12, wherein said amplifier means comprises a passive network electric circuit.

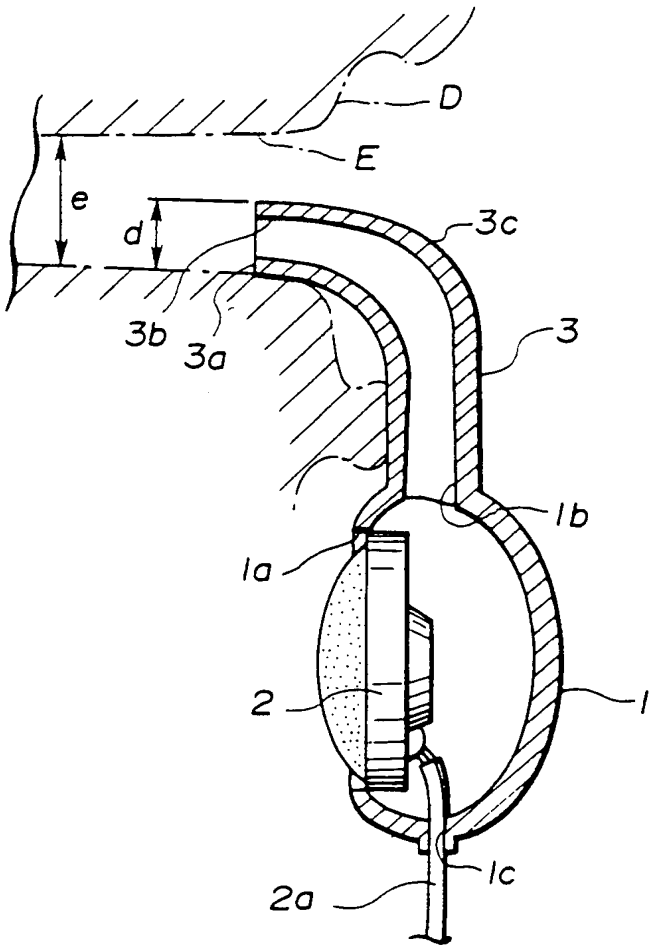

FIG.1

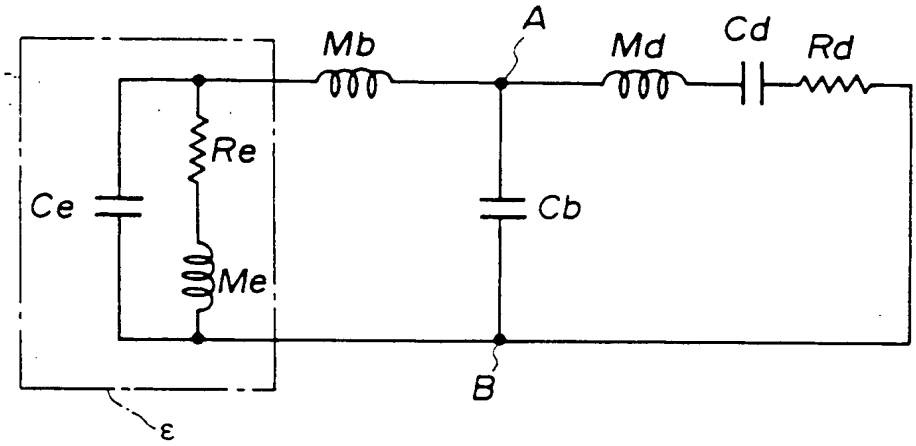

FIG.2

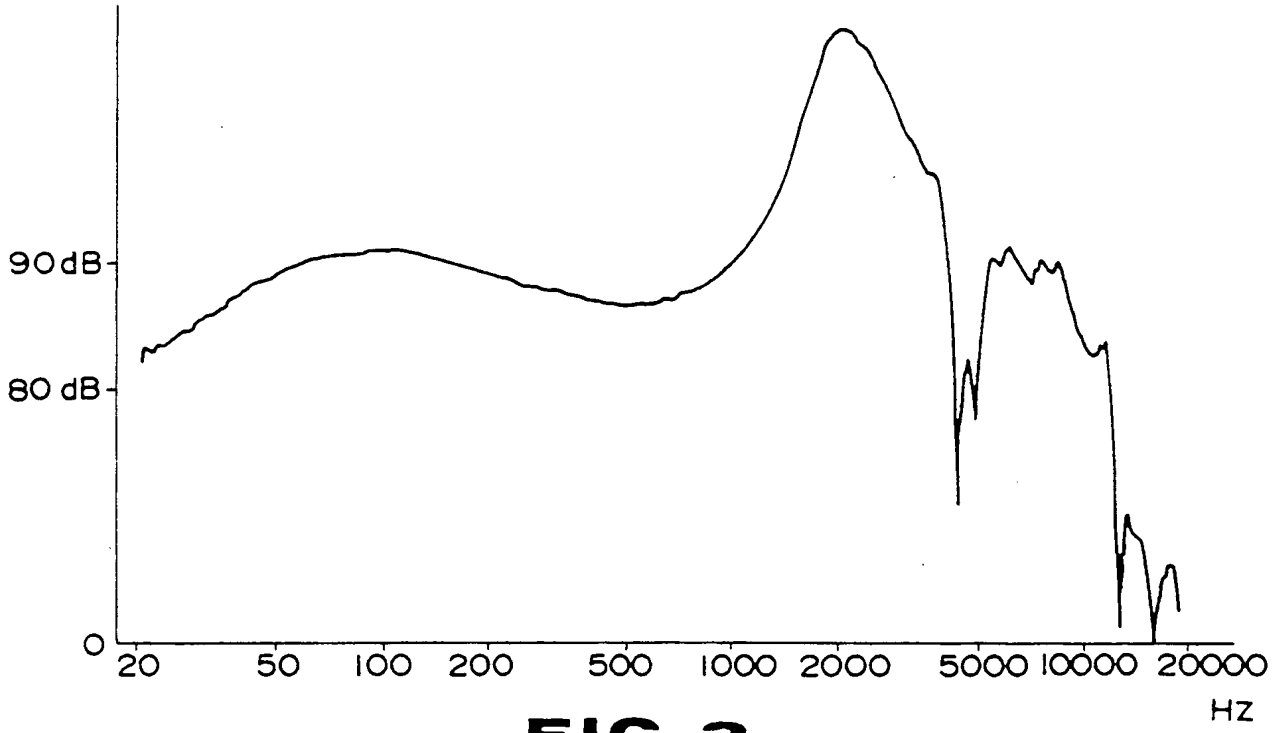
90dB
80 dB
0
20
50
100
200
500
1000
2000
5000
10000
20000
HZ

FIG. 3

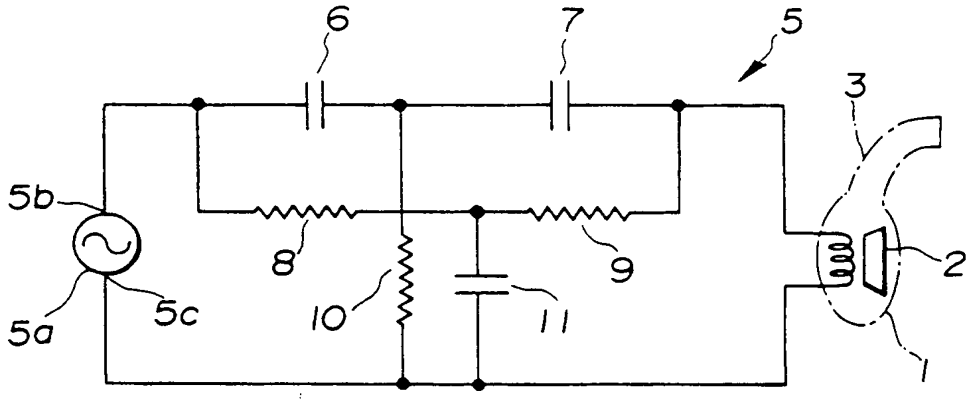
6
7
5
3
5b
8
9
2
10
11
5a
5c
1

FIG. 4

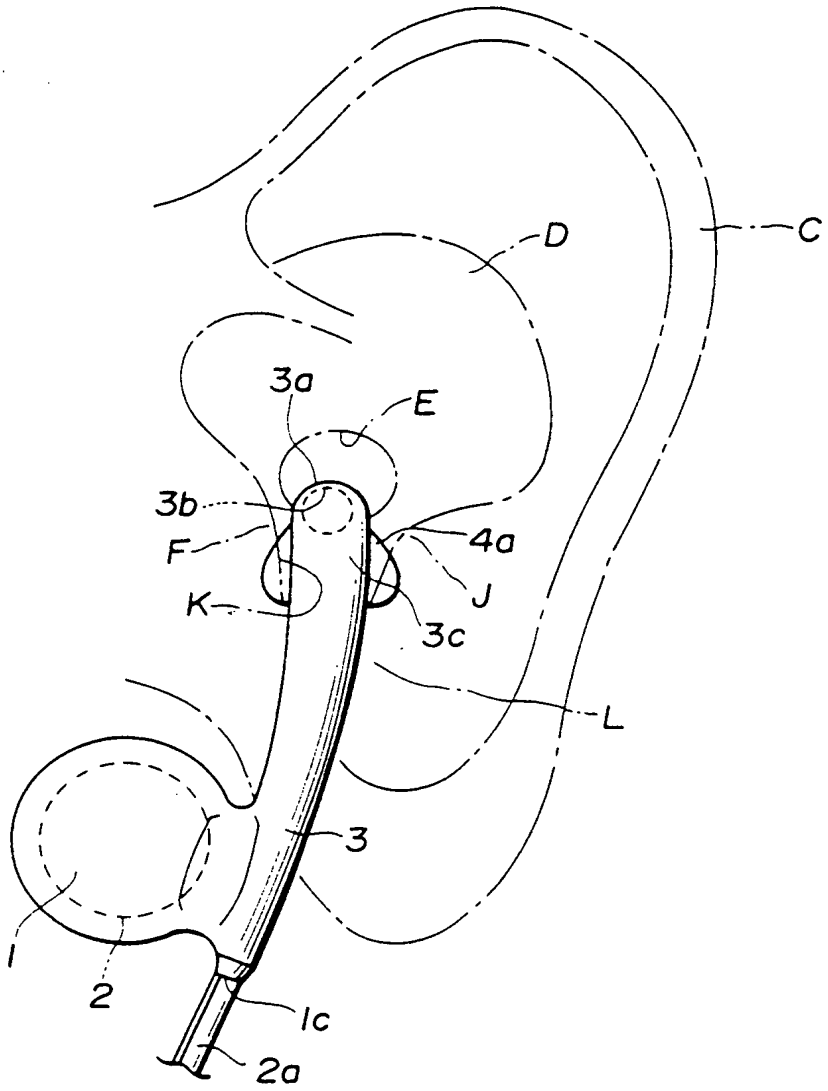

FIG. 5A

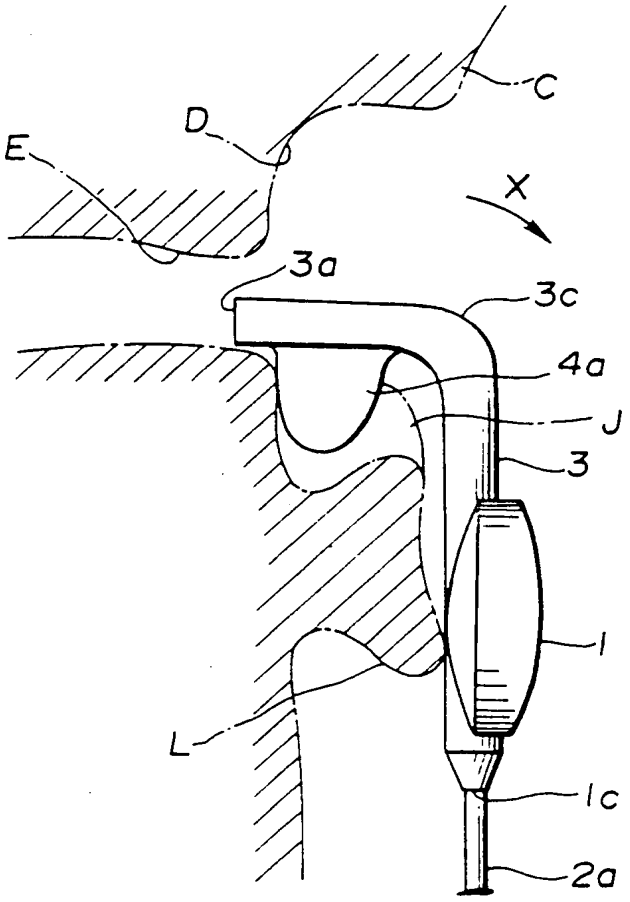

FIG. 5B

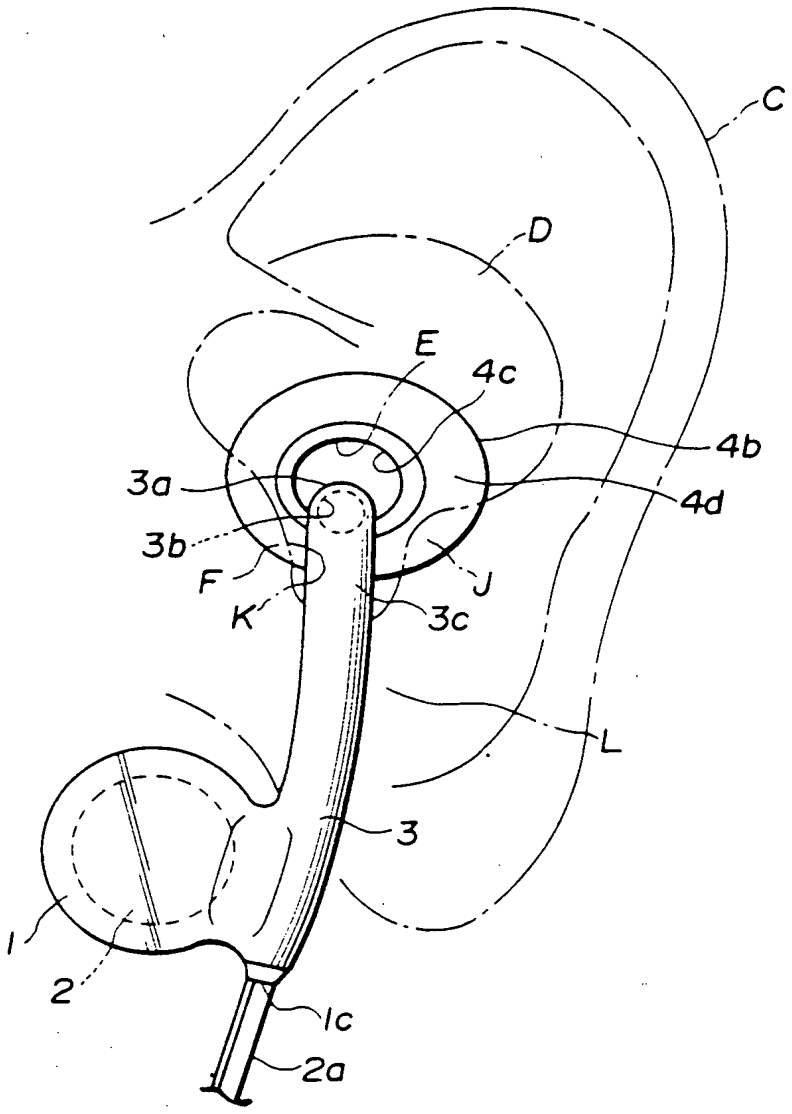

FIG.6A

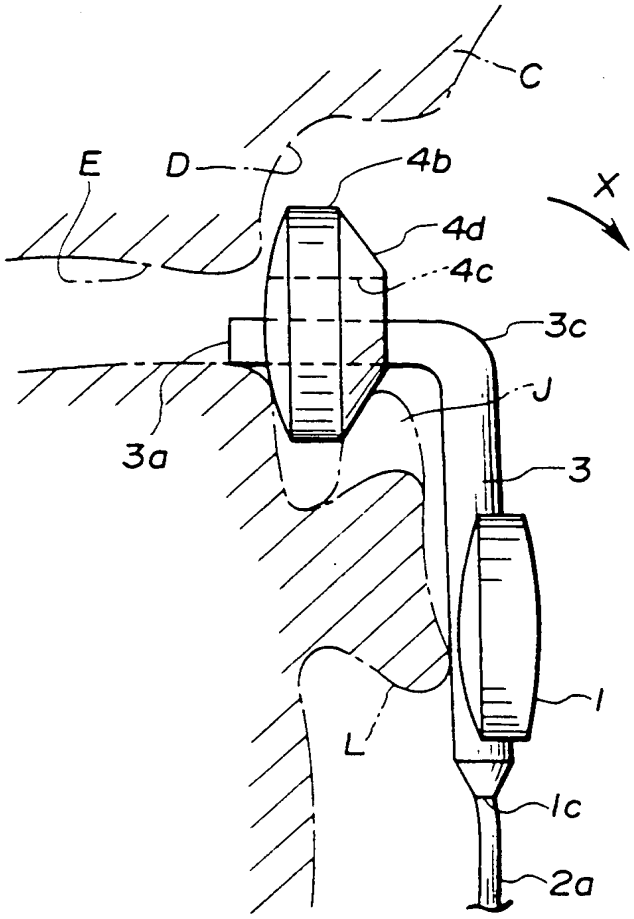

FIG.6B

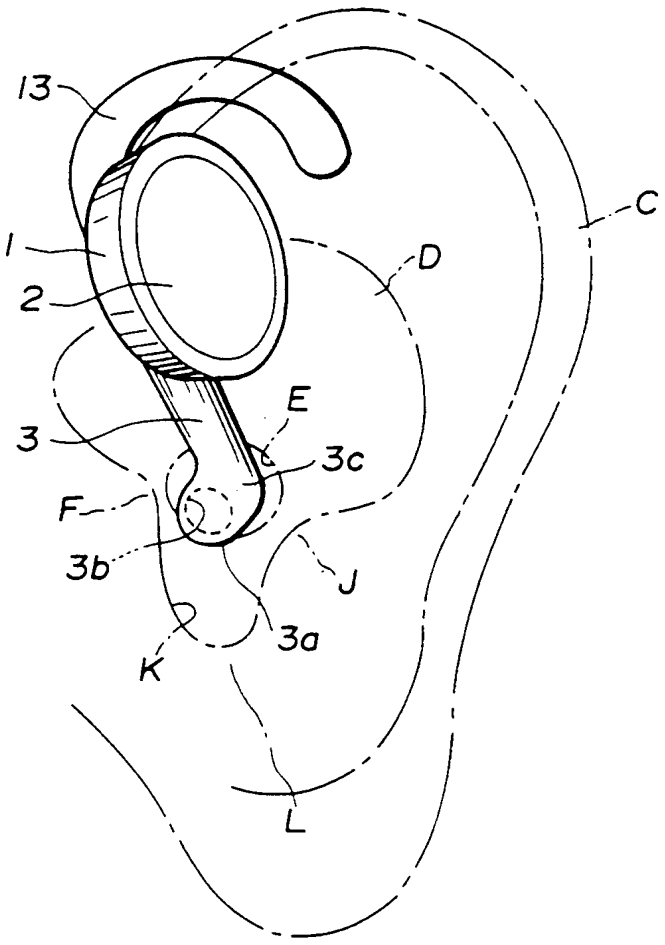

FIG.7

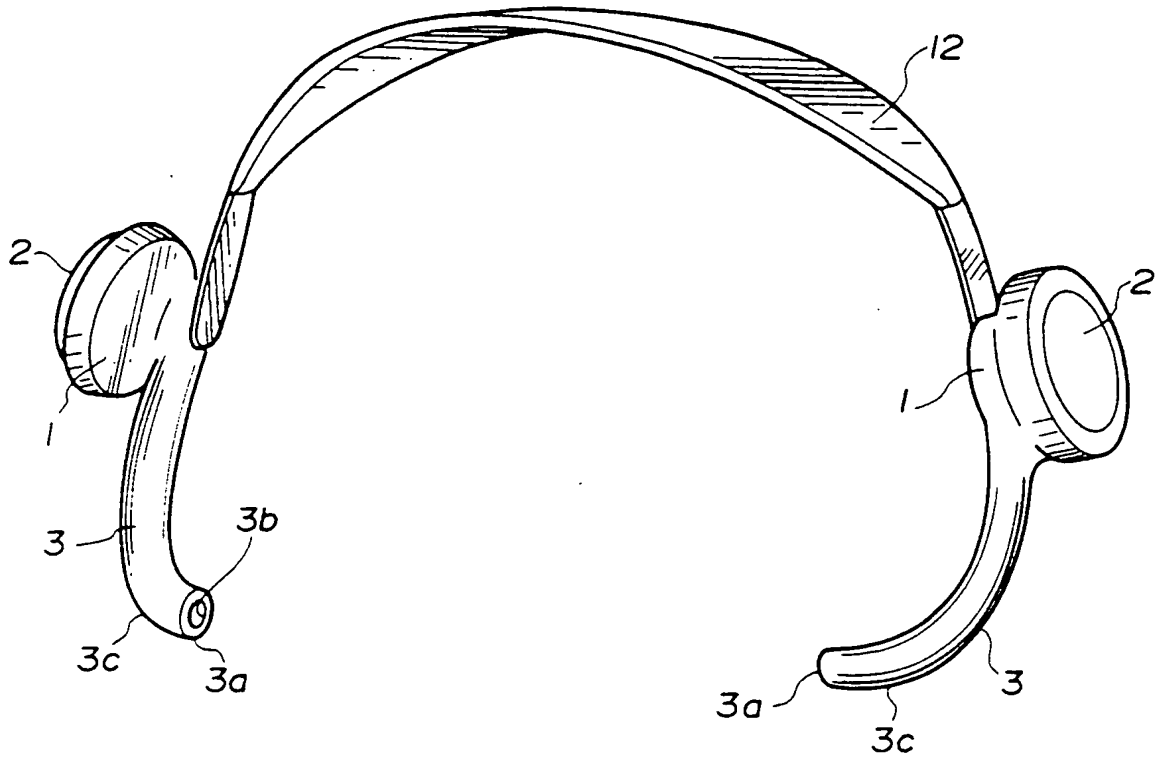

FIG.8

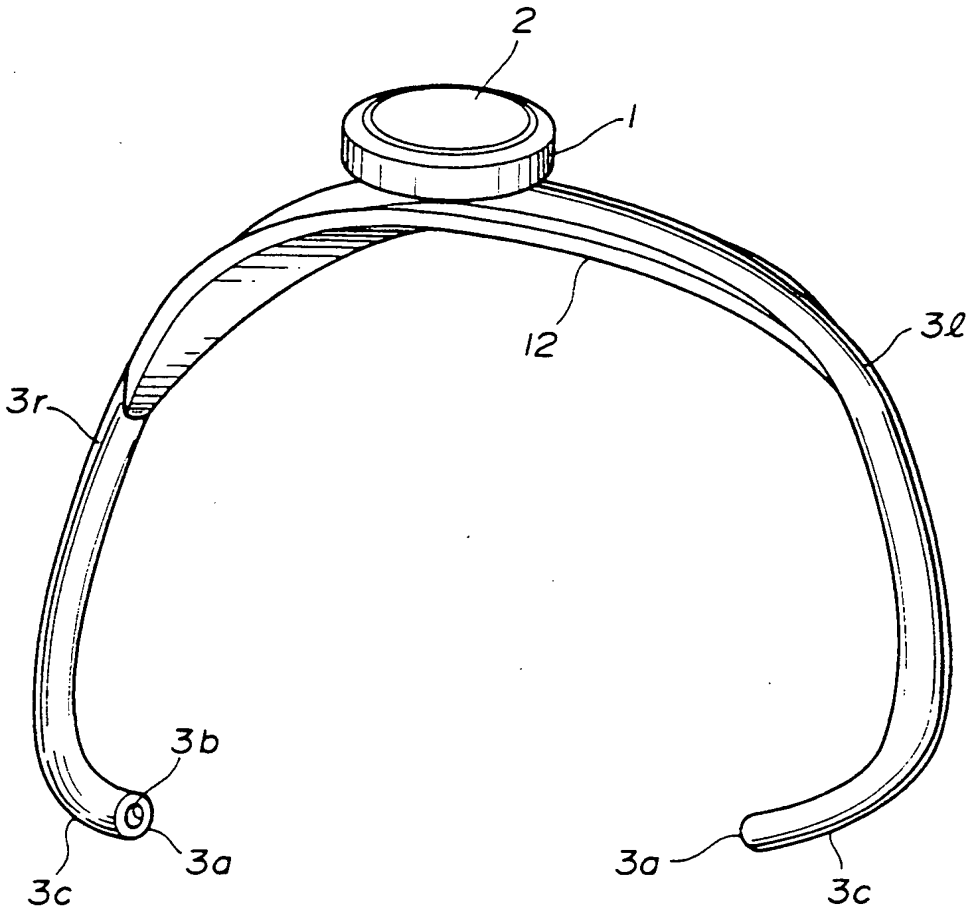

FIG. 9

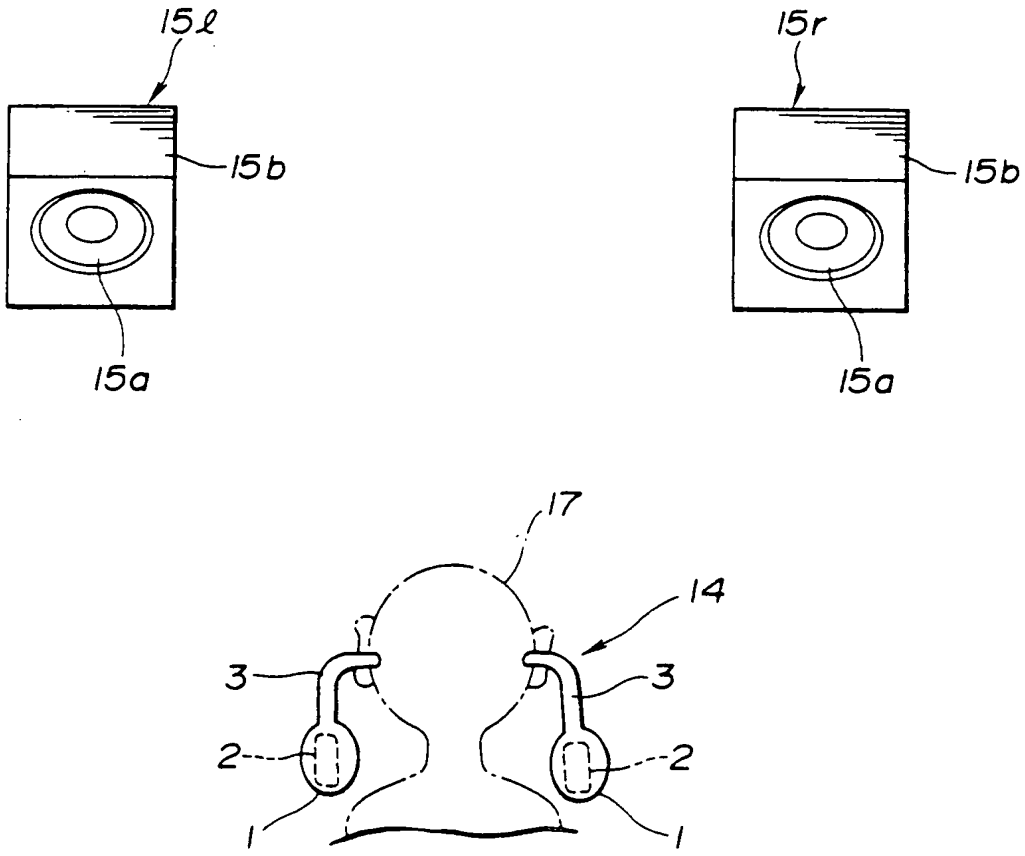

FIG.10

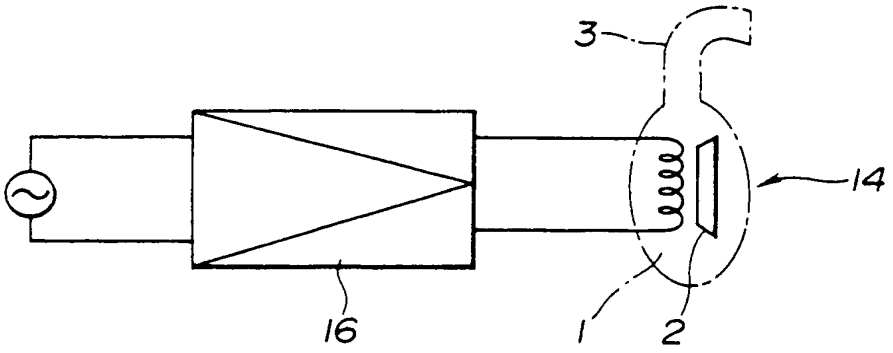
3
14
16
1
2

FIG.11

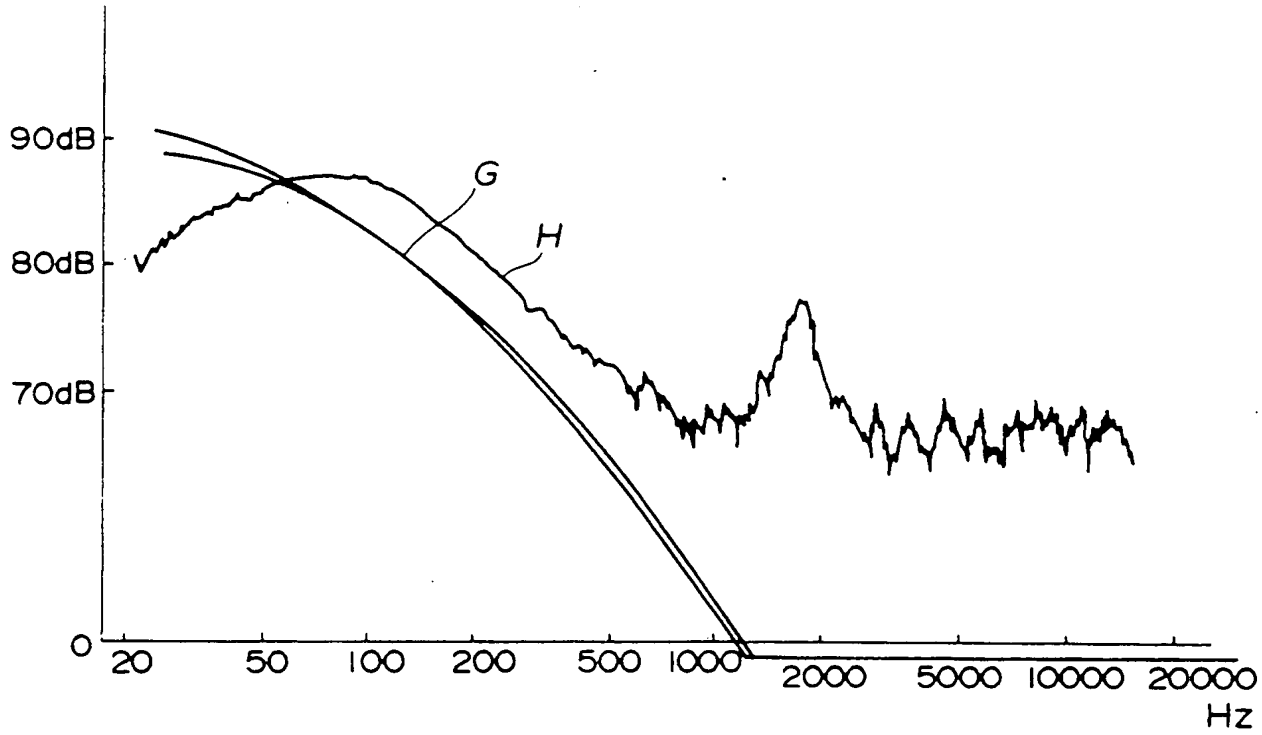
90dB
80dB
70dB
0
G
H
20
50
100
200
500
1000
2000
5000
10000
20000
Hz

FIG.12

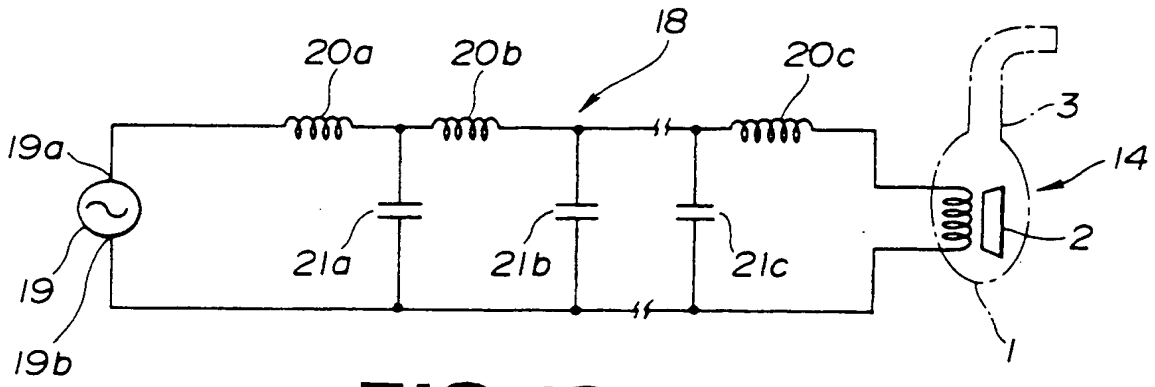
18
20a
20b
20c
3
14
19a
2
21a
21b
21c
19
19b
1

FIG.13

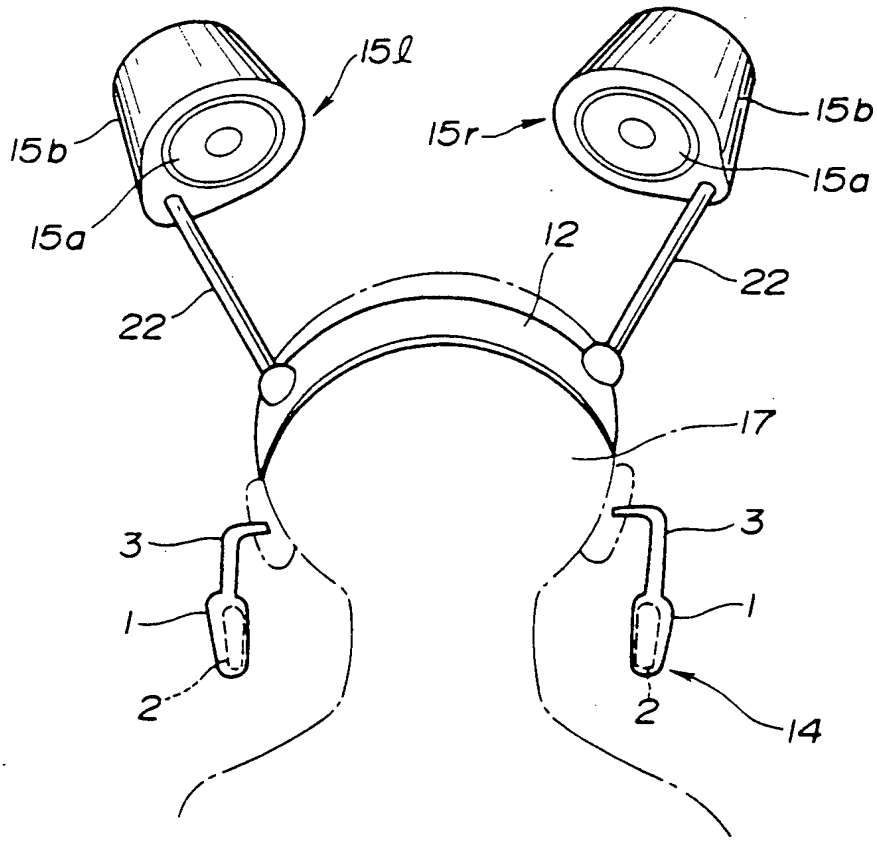
15ℓ
15r
15b
15b
15a
15a
12
22
22
17
3
3
1
1
2
2
14

FIG.14

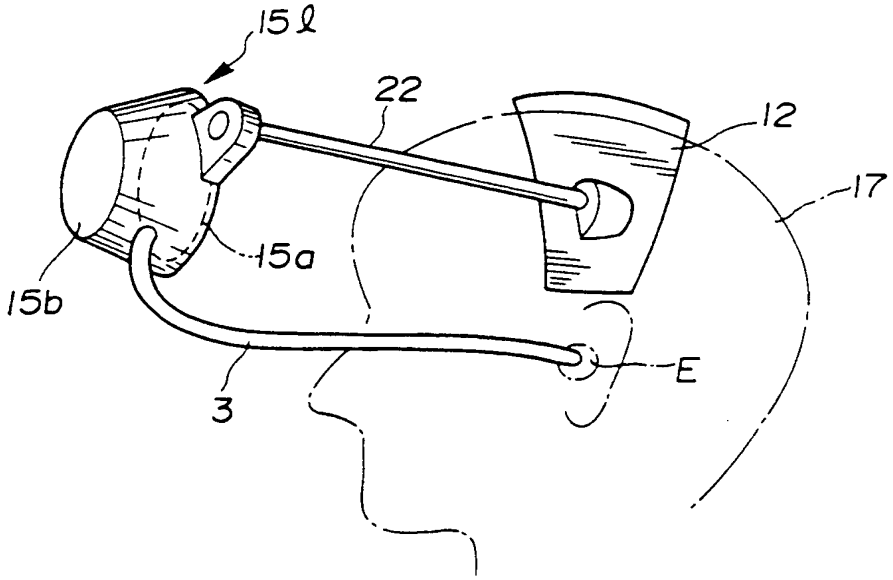

FIG.15

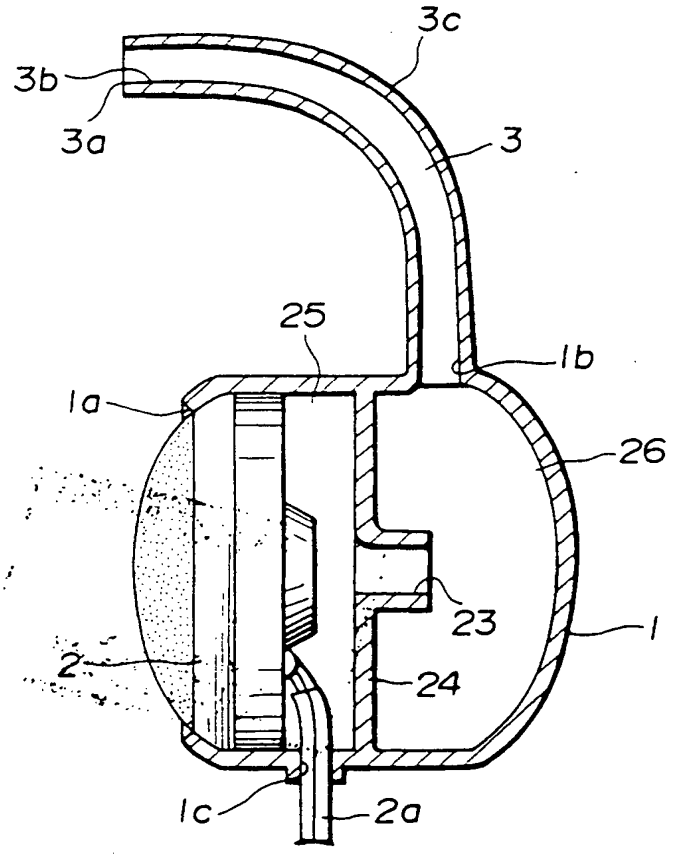

FIG.16

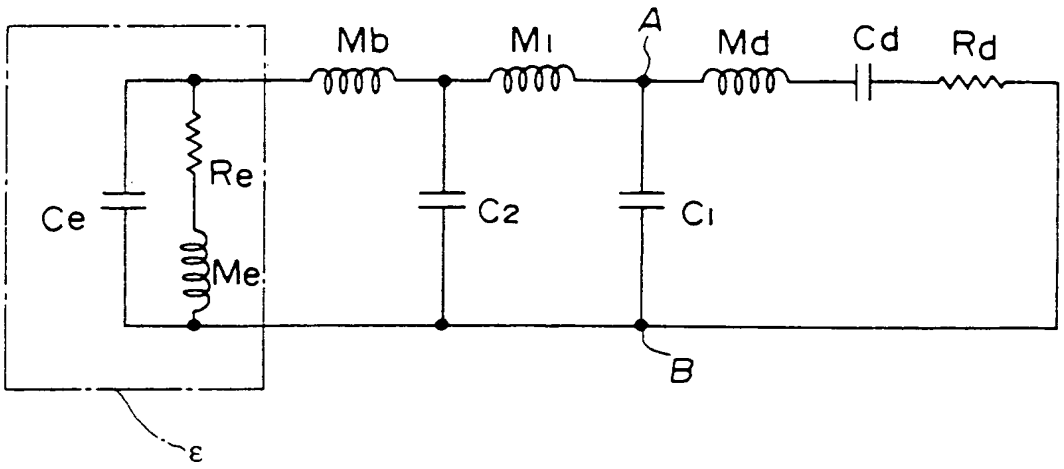
Mb
M1
A
Md
Cd
Rd
Re
Ce
C2
C1
Me
B
ε

FIG.17

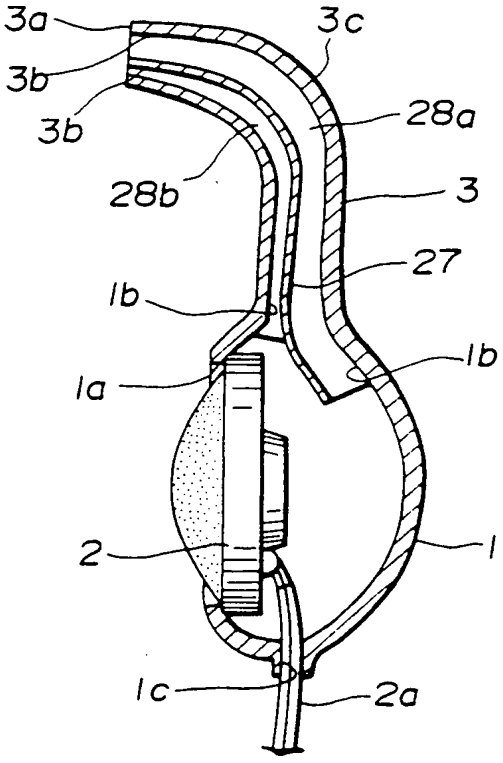
3a
3c
3b
3b
28a
28b
3
27
1b
1b
1a
2
1
1c
2a

FIG.18

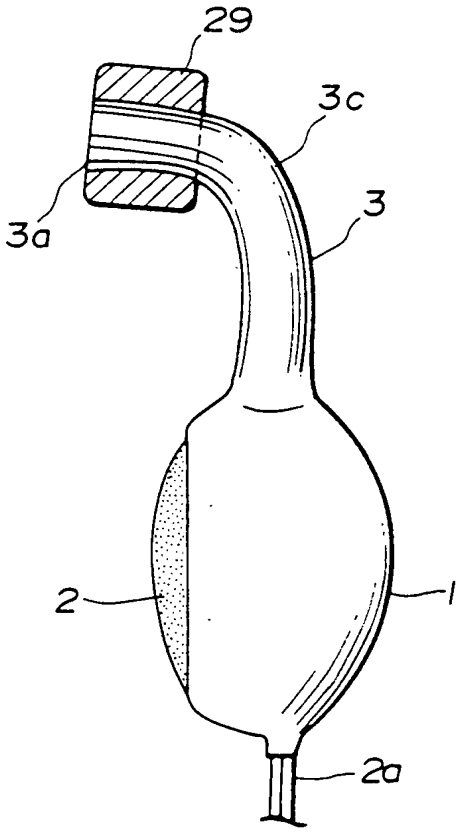

FIG.19

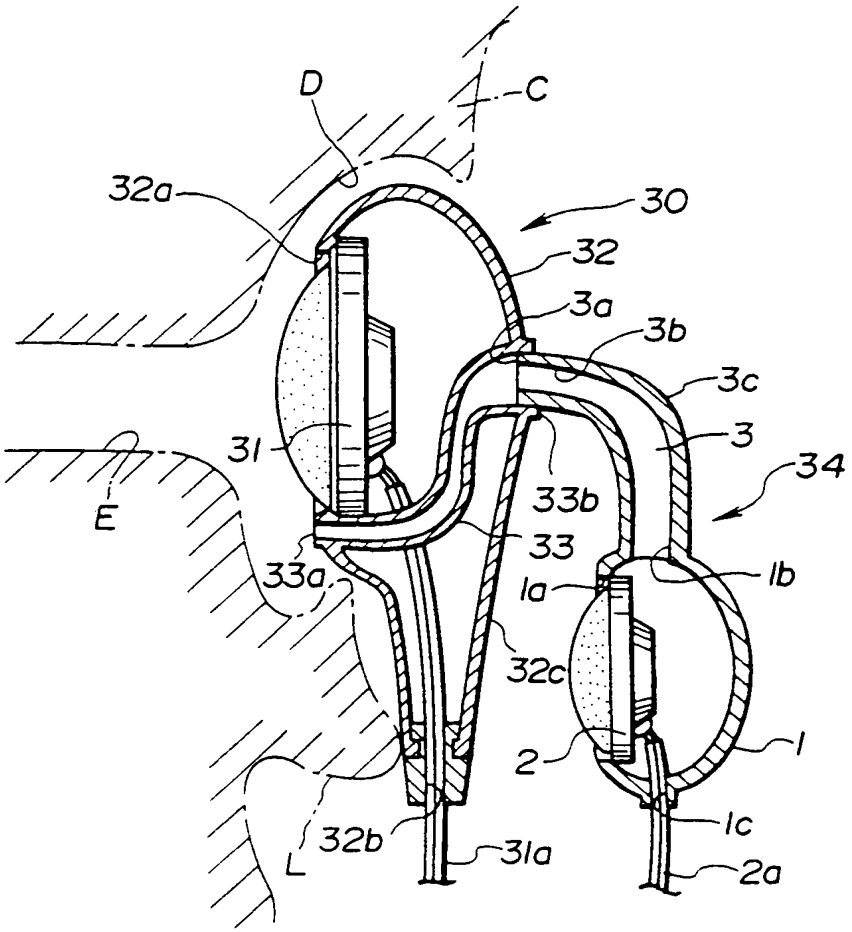

FIG.20

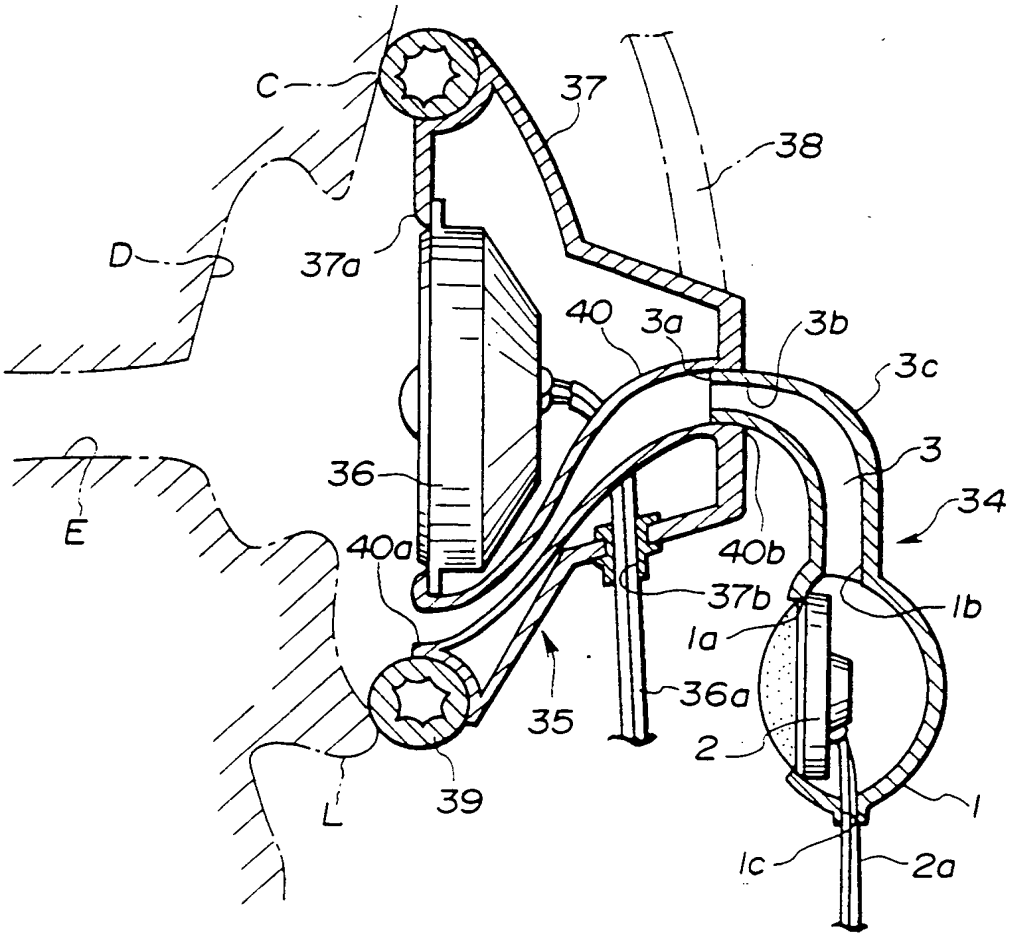
C
37
38
D
37a
40
3a
3b
3c
3
34
36
E
40a
40b
37b
1b
1a
36a
35
2
39
L
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FIG.21

(19) Office européen des brevets

(11) Publication number: **0 421 681 A3**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **90310624.3**

(51) Int. Cl.5: **H04R 1/10**, H04R 1/28

(22) Date of filing: **28.09.90**

(30) Priority: **30.09.89 JP 255797/89**

(43) Date of publication of application:
10.04.91 Bulletin 91/15

(84) Designated Contracting States:
DE FR GB NL

(88) Date of deferred publication of the search report:
22.07.92 Bulletin 92/30

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(54) Electro-acoustic transducer and sound reproducing system.

(57) An electro-acoustic transducer comprising
an electro-acoustic transducer accommodated in a cabinet, and
a sound guide tube for conducting the sound from the electro-acoustic transducer unit out of said cabinet,
said sound guide tube being of a lesser diameter than the external acoustic miatus to allow at least the sound radiating end of the sound guide tube to be introduced into the external auditory miatus.

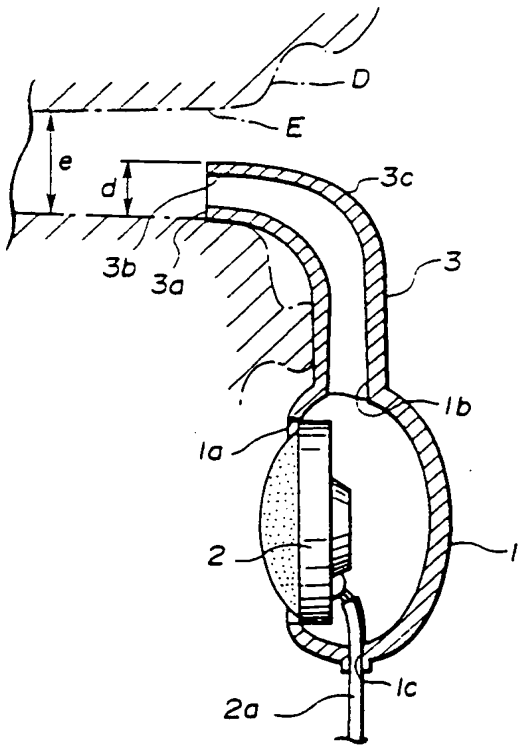

FIG.1

EP 0 421 681 A3

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EUROPEAN SEARCH REPORT

Application Number

EP 90 31 0624

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	FR-A-2 604 589 (TEMCO) * Page 1, lines 5-12; page 3, lines 21-26; page 5, line 14 - page 6, line 29 *	1-3	H 04 R 1/10 H 04 R 1/28
A	GB-A-2 078 057 (SONY) * Page 1, lines 28-35,47-91 *	1,4-6	
A	PATENT ABSTRACTS OF JAPAN, vol. 9, no. 295 (E-360)[2018], 21st November 1985; & JP-A-60 134 599 (FUJIO SHIINA) 17-07-1985	1,4,7	
A	FR-A-2 599 922 (DODIC) * Page 1, line 29 - page 2, line 2; page 4, line 37 - page 5, line 12 *	1,4,8,9	
A	EP-A-0 314 419 (SONY) * Column 1, lines 2-5; column 2, lines 32-57; column 5, lines 24-36 *	1,10	
A	US-A-3 995 113 (TANI) * Column 2, lines 31-40; column 4, line 14 - column 5, line 40 *	1,11	TECHNICAL FIELDS SEARCHED (Int. Cl.5) H 04 R
A	EP-A-0 270 857 (EVER CLEAN) * Column 1, lines 1-5; column 4, lines 29-51 *	12	
A	US-A-4 682 363 (GOLDFARB et al.) * Column 2, lines 24-41; column 3, line 25 - column 4, line 6 *	12	
A	US-A-4 383 134 (VON RECKLINGHAUSEN) * Column 1, lines 5-7; column 2, lines 23-28; column 5, line 42 - column 6, line 9 *	12-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-04-1992	ZANTI P.V.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)

European Patent Office

EP 90 31 0624

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid,

namely claims:

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions.

namely:

See sheet -B-

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid.

namely claims:

☐ None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims.

namely claims:

European Patent Office

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims 1-11: Electro-acoustic transducer accomodated in a cabinet; a sound guide tube, being of lesser diameter than the external acoustic miatus.

2. Claims 12-15: The electro-acoustic transducer; the sound guide tube; and a sound reproducing apparatus.